Laser Induced Fluorescence in Inhibited Counterflow Diffusion Flames

Robert G. Daniel
U.S. Army Research Laboratory
Weapons and Materials Research Directorate
AMSRL - WM - PC
Aberdeen Proving Ground, MD 21005
Ph: 410-278-6806
Fax: 410-278-6150
email: rdaniel@arl.mil

Kevin L. McNesby
U.S. Army Research Laboratory
Weapons and Materials Research Directorate
AMSRL - WM - PC
Aberdeen Proving Ground, MD 21005
Ph: 410-278-6163
Fax: 410-278-6150
email: mcnesby@arl.mil

R. Reed Skaggs
U.S. Army Research Laboratory
Weapons and Materials Research Directorate
AMSRL - WM - PC
Aberdeen Proving Ground, MD 21005
Ph: 410-278-6110
Fax: 410-278-6150
email: rskaggs@arl.mil

Andrzej W. Miziolek
U.S. Army Research Laboratory
Weapons and Materials Research Directorate
AMSRL - WM - PC
Aberdeen Proving Ground, MD 21005
Ph: 410-278-6157
Fax: 410-278-6150
email: miziolek@arl.mil

Barrie E. Homan
U.S. Army Research Laboratory
Weapons and Materials Research Directorate
AMSRL - WM - PC
Aberdeen Proving Ground, MD 21005
Ph: 410-278-9991
Fax: 410-278-6150
email: bhoman@arl.mil

ABSTRACT: We are studying counterflow diffusion flames inhibited with several agents via modeling and laser induced fluorescence of H, O, and OH in order to understand the fundamental suppression mechanism of iron pentacarbonyl.

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Robert G. Daniel, R. Reed Skaggs, Barrie E. Homan,
Andrzej W. Miziolek, and Kevin L. McNesby
U. S. Army Research Laboratory
Weapons and Materials Research Directorate
Aberdeen Proving Ground, Maryland 21005-5066

INTRODUCTION: As part of the continuing effort to find an effective, yet safe, replacement compound for the commonly used halon fire suppression agents, we have begun a study of reduced pressure counterflow diffusion flames inhibited with iron pentacarbonyl ($Fe(CO)_5$). Iron pentacarbonyl has been shown to be a very effective fire suppression agent in small quantities, but there is little understanding of the mechanism of its activity. The goal of this study is to understand the mechanism by which $Fe(CO)_5$ inhibits flames by coupling experimental measurements with computer modeling of diffusion flames. This project is part of the Next Generation Fire Suppression Program (NGFSP).

We will present results from the spectroscopic examination of uninhibited and inhibited counterflow diffusion flames via laser induced fluorescence of active flame species at two reduced pressures. The species studied are atomic oxygen (O), atomic hydrogen (H), and hydroxyl radical (OH). The flames under study have also been examined with thermocouple probes to map temperature profiles and emission spectroscopy of active species including OH, CH, C_2, and iron and iron containing compounds. We have also performed flame extinction studies which determine the strain rate for flame extinction as a function of inhibitant concentration.

EXPERIMENTAL: The experiments utilize a counterflow diffusion burner schematically shown in figure 1 as the flame source, an excimer pumped (XeCl) dye laser, and a light collection train. The fuel and any additive flows from the bottom burner head, and the oxidizer (manufactured air) and additive flows from the top. The two flows collide and form a stagnation plane, a region of near zero vertical flow velocity. The fuel will diffuse upward into the oxidizer flow to a stoichiometric region which will support the flame front. The two burner heads are mounted on XZ translation stages to allow the full vertical spatial distribution to be mapped with a fixed optical probe, defined by the laser focus.

The early experiments centered on the emission spectra of the flame, in which many

flame species were mapped by their emission. A two dimensional CCD camera was used to obtain both spatial (distance between burner heads) and wavelength information. The spectra was dispersed with a 500 mm monochromator, which allowed the camera to image a 20 nm region. Spatially, the camera maps approximately 11 mm. A example of the information from an OH spectrum is shown in figure 2.

We are studying reduced pressure (50 and 300 torr) and "atmospheric" (700 torr) flames to increase the understanding of the mechanism of suppression of iron pentacarbonyl, a prototypical fire suppression superagent. Output from the dye laser is focused through a LiF window into the flame, with the fluorescence being collected at a right angle by a 2 inch lens. The fluorescence is focused onto the active element of a photomultiplier tube, whose signal is passed to a lockin amplifier and boxcar for signal averaging.

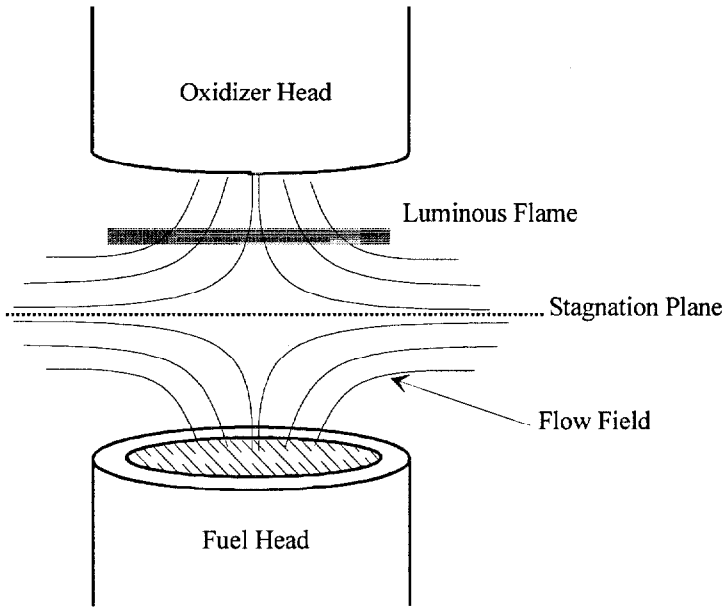
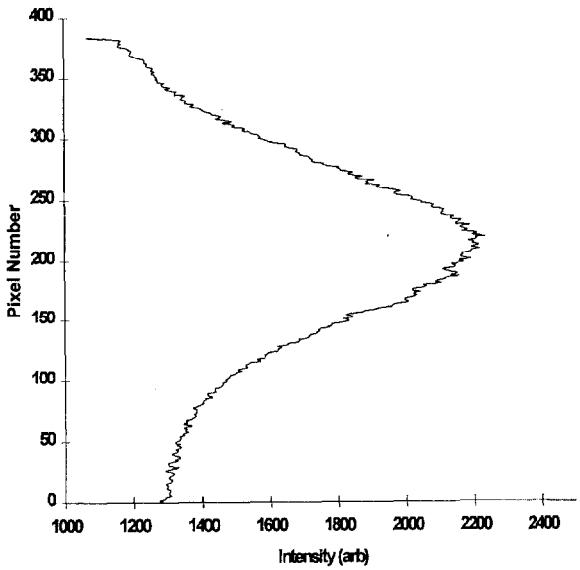


Figure 1. Schematic of a counterflow diffusion burner with the locations of the flame front and stagnation plane indicated. The laser focus will be fixed and the burner heads moved vertically to map the spatial distribution of the species O, H, and OH.

DISCUSSION: We will present the results of continuing experiments designed to map the spatial dstribution of oxygen, hydrogen, and hydroxyl radical. This information will be added to the body of information already existing from emission and thermocouple measurements. The results and their implications will be presented and discussed.



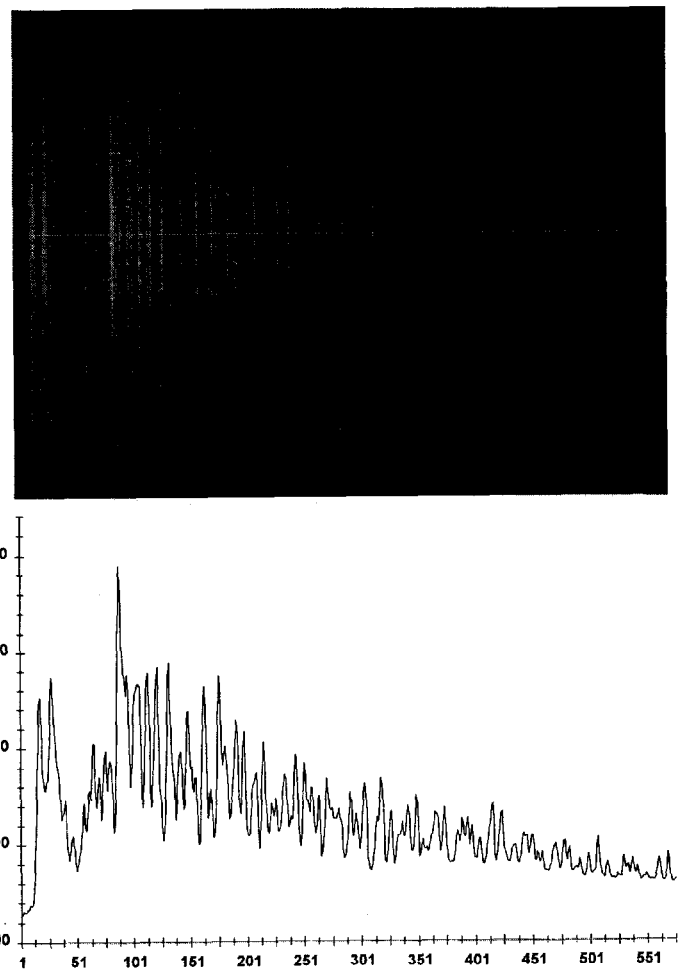


Figure 2. Upper right is a sample of the emission spectra of OH located around 308 nm. To the left is a summed x-cross section of the spectra which gives the vertical spatial profile of OH in the flame. On the bottom is the summed y-cross section to produce the spectrum in one dimension.